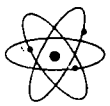
TENORM in Phosphate Mining

Jon Richards, EPA Region 4, Radiation Technical Support

TENORM

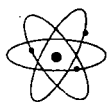
- Technically Enhanced Naturally Occurring Radioactive Material – are any naturally occurring radioactive materials not subject to regulation under the Atomic Energy Act *whose radionuclide concentrations or potential for human exposure have been increased* above levels encountered in the natural state by human activities
- Natural radioactivity, or NORM – not disturbed by human activity [can include anthropogenic, e.g. global fallout: Cs137, Pu239]; TENORM is human-related movement or concentration of what was formerly natural radionuclides.

TENORM



- EPA/states regulations:
  - Some states regulate TENORM, most are oil states. Many have adopted the CRCPD's recommended 100 mrem/yr guide.
  - FL's Bureau of Radiation Control – Environmental Radiation Stds for *inside of bldgs & performs tests both prior to phosphate mining and* subsequent to reclamation
  - NRC does not regulate TENORM, per the Atomic Energy Act [1954]; DOE has guidance similar to UMTRCA in their Orders
  - EPA regulates TENORM radionuclides under CAA, CWA, SDWA, CERCLA, UMTRCA [1978] & 40 CFR 192
  - EPA's radiation website: definition, regs: http://www.epa.gov/radiation/tenorm/about.html

Regulations & Limits



- EPA's Radiation regulations/guidance
- Radiation doses are risk-based:
  - NESHAP for public: 10 mrem/year
  - Drinking Water [includes NORM]: 4 mrem/yr for beta/gamma emitters; gross alpha: 15 pCi/L; Total Radium: 5 pCi/L;
  - uranium 30 ug/L
  - TRU & HLW: 15 mrem/yr
  - Superfund website: showing radiation regulations: http://intranet.epa.gov/osrti/ard/spb/radiation/related.html

Review of 40 CFR 192

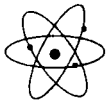
- **Announcement: EPA is reviewing and potentially revising its Health and Environmental Standards for Uranium and Thorium Milling Facilities**
- changes in uranium industry technologies (such as utilization of the In Situ Leaching recovery process as the principal current technology for extracting uranium) and their potential environmental impacts
- revisions in EPA drinking and groundwater protection standards
- judicial decisions concerning the existing regulations
- issues relating to environmental justice, Tribal, and low-income populations
- updated dose and risk factors, and scenarios, for assessing radiological and nonradiological risk
- facilities proposed in states outside existing uranium mining and milling areas
- costs and benefits of possible revisions

FAQs for TENORM

- ***Where does the radioactivity in TENORM come from?***
  Radium-226 is the principal source of human exposure to radiation from natural surroundings. It is a decay product of uranium and thorium and has a half-life of 1600 years. Radium-226 is commonly found in TENORM materials and wastes. Concentrations in TENORM materials range from undetectable amounts to as much as several hundred thousand picocuries per gram (pCi/g). Typical natural concentrations in US soils range from less than 1 to 4 pCi/g.

- ***Where is TENORM found and where does it come from?***
- TENORM can be found in all 50 states -- anywhere industrial processes (such as mining) that generate it take place. The production of phosphate for fertilizer and associated TENORM waste is predominately in the southeastern U.S. (Fl, SC & NC), but also includes some Western states.
- TENORM waste from oil and gas production is of greatest concern in the Gulf States, upper Midwest, and some Appalachian states. TENORM is generated by certain industrial activities, such as mining, fertilizer production, and oil and gas production. Trace amounts of TENORM may be found in some consumer products when certain minerals are used in the manufacturing process.

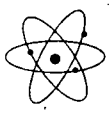
TENORM in Coal Ash



- typical radiation levels in coal ash:

Wastes	**Radium/Uranium Levels [pCi/g]**		
	low	*average*	*high*
Bottom Ash	1.6	3.5-4.6	7.7
Fly Ash	2	5.8	9.7

Oil and Gas Production Wastes



- Much of the petroleum in the earth's crust was created at the site of ancients seas by the decay of sea life. As a result, petroleum deposits often occur in aquifers containing brine (salt water). Radionuclides, along with other minerals that are dissolved in the brine, precipitate (separate and settle) out forming various wastes at the surface:
- mineral scales inside pipes
- sludges
- contaminated equipment or components
- produced waters.
- Because the extraction process concentrates the naturally occurring radionuclides and exposes them to the surface environment and human contact, these wastes are classified as TENORM.

TENORM in Phosphate Mining

- **Radiation in Phosphogypsum**
- Phosphogypsum contains appreciable quantities of uranium and its decay products, such as radium-226, due to their high concentrations in phosphate ores. **Uranium in phosphate ores found in the U.S. ranges in concentration from 7 to 100 pCi/g.**
- During the wet process, radionuclides present in the phosphate ore are selectively separated and concentrated. Around 80 percent of the radium-226 becomes concentrated in the phosphogypsum. **Radium concentrations at phosphogypsum stacks range from 11 to 35 pCi/g.**
- Radon (Rn-222) can be found emanating from the surface of phosphogypsum stacks. Average radon fluxes range from 1.7 to 12 pCi/m2-sec and can be as high as 340 pCi/m2-sec, with a mean value of 6.8 pCi/m2-sec.
- Radiation levels in phosphogypsum vary considerably from stack to stack and from different locations in a single stack due to a number of factors:
- radium concentration in the phosphate rock
- emanation rate, vegetation cover, porosity, moisture content,
- presence of standing water, temperature/barometric pressure.
- The table below shows the range of activity in fertilizer production wastes [table on website]

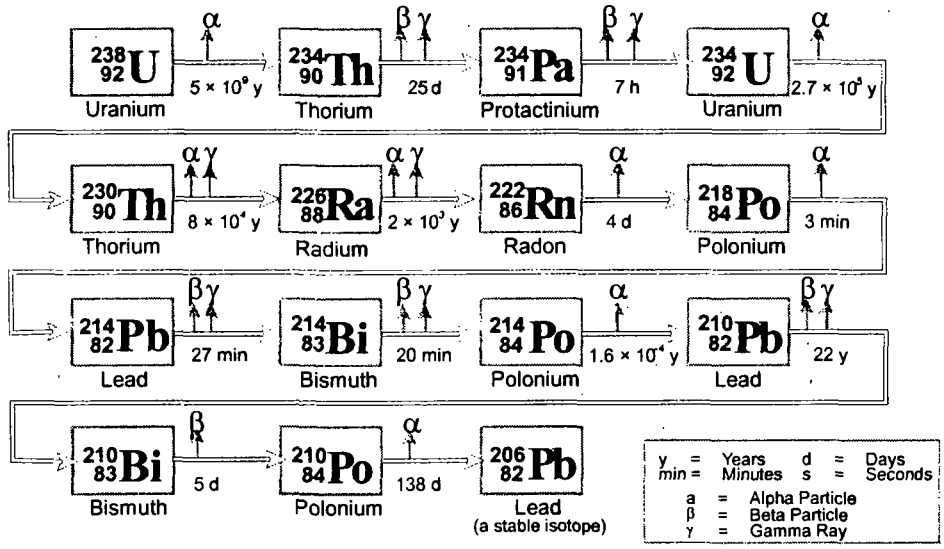
Radium Levels in Phosphate

- The table below shows the range of activity in fertilizer production wastes:

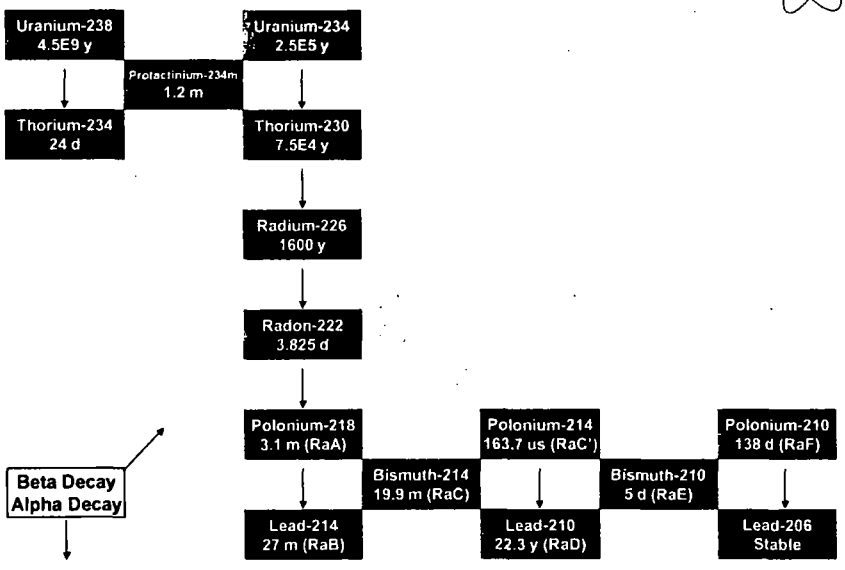
Source	**Radium/Uranium Levels [pCi/g]**		
	low	**average**	**high**
Phosphate Ore (Florida)	7	17.3-39.5	53.5
Phosphogypsum	7.3	11.7-24.5	36.7

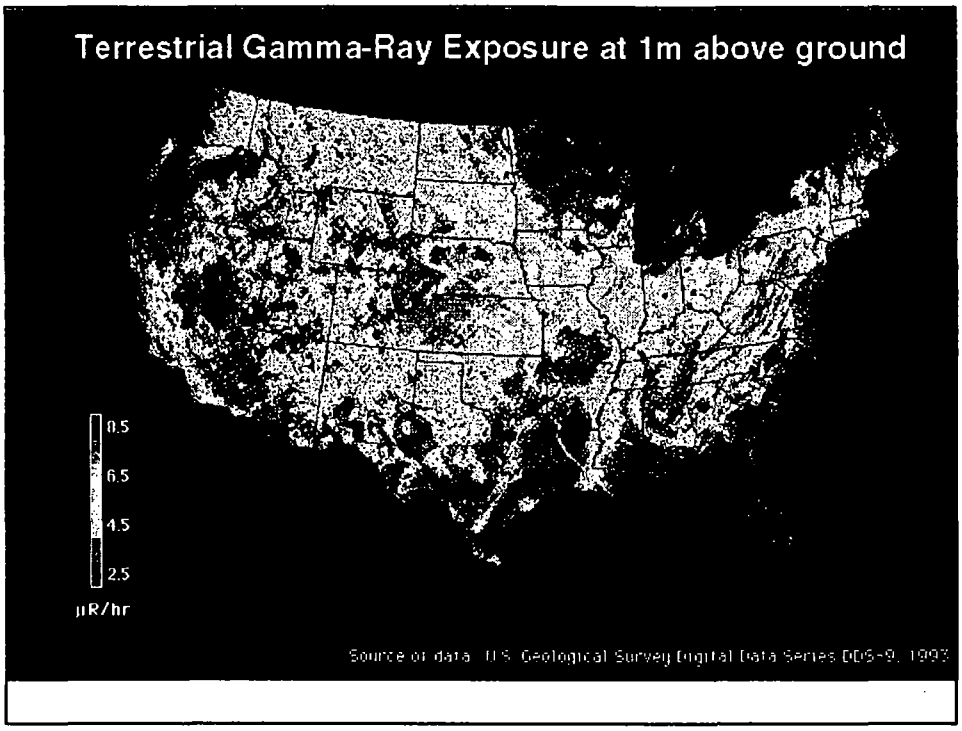
Decay Schemes

Radioactive Disintegration Series for Uranium 238



Uranium Decay Series

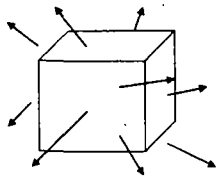




Radioactivity vs. Dose

- Radioactivity is disintegrations per second (dps)
  - Unit is picocurie (pCi) = 0.037 dps [= 1 Bq]
  - Unique decay rates, energies, and half lives for each radionuclide
  - Depending on radionuclide, decay can be α or β, usually with one or more γ
  - Energy per decay is sum of particle and gamma energies
- Dose is energy deposited in a unit mass of a medium (e.g., per gram of tissue)
- Same activity of different radionuclides ≠ same dose (depends on energy per decay)

Units of radioactivity



How many disintegrations per second are going on in that material? i.e. How radioactive is it?

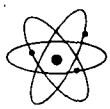
'Old' {still used!} Units
1 curie (Ci) = that amount of material in which 37 billion disintegrations per sec are occurring. (1 Ci = 1 gram of radium)

New International Units:
1 becquerel (Bq) = that amount of material in which 1 disintegration per second is occurring. [e.g. 27 pCi = 1 Bq = 1dps
& 1 pCi = 2.22 dpm]

Atoms and Radioisotopes – Half-Life

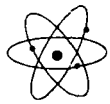
- The rate of radioactive decay is characteristic & unique of each radionuclide
- Biological half-life: radionuclide in the body via ingestion, inhalation [e.g. H3~ 10d ½ life-bio]
- Effective half-life: in environment [e.g. H3 = 12.3yr ½ life

Radiation Background



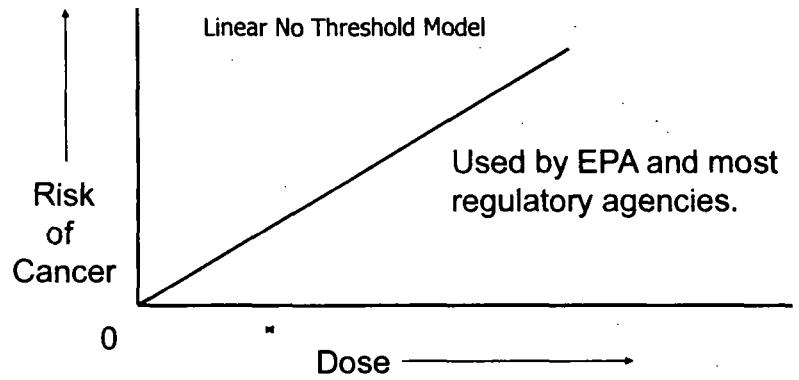
- 2 types: General = all kinds & sources ;
  specific = radionuclide specific bkgd conc'ns
- Radionuclide background levels are determined just like for metals: site-specific
- Ra226: US bkgd ~= 0.2 - 3 pCi/g, FL ~1 pCi/g
- U238: ~ = 0.2 to 2.8 pCi/g in FL natural soils

Radiation Acute vs Chronic Effects



- Acute Radiation Doses measured in Rem, not millirem [1000 mrem = 1 rem]
- EPA PAG levels: 1 rem, 5 rem [1 yr, 2yr,50yr]
- EPA Emergency Worker Dose Guidance: 5 rem = all; 10 rem =protecting property; 25 rem = saving lives
- Radiation acute effects:
  - < 5-10 rem: no observable acute effects
  - 5-10 rem: changes in blood chemistry, skin burns
  - 50-100 rem: nausea, fatigue, vomiting, hair loss, diarrhea
  - 300-500 rem: fatal with or without medical care
  - > 500 rem: almost always fatal

Low dose cancer risk model



Radiation Dose Response

- LinearNonThreshold use reaffirmed: "...current scientific evidence is consistent with the hypothesis that there is a linear, no-threshold dose-response relationship between exposure to ionizing radiation and the development of cancer in humans." (BEIR VII, '05)
- Natl Academy of Science, Biological Effects of Ionizing Radiation: 7 reports over 25 yrs